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Microplastics in sub-surface waters of the Arctic Central Basin

La Daana K. Kanhai[a,b,*], Katarina Gårdfeldt[c], Olga Lyashevska[a], Martin Hassellöv[d], Richard C. Thompson[b], Ian O'Connor[a]

[a] Marine and Freshwater Research Centre, Galway Mayo Institute of Technology, Dublin Road, Galway, Ireland
[b] Marine Biology and Ecology Research Centre, School of Biological and Marine Sciences, Plymouth University, Drake Circus, Plymouth, Devon PL4 8AA, United Kingdom
[c] Department of Chemistry and Chemical Engineering, Chalmers University of Technology, Göteborg SE-412 96, Sweden
[d] Department of Chemistry and Molecular Biology, University of Gothenburg, Göteborg, Sweden

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ABSTRACT

Polar oceans, though remote in location, are not immune to the accumulation of plastic debris. The present study, investigated for the first time, the abundance, distribution and composition of microplastics in sub-surface waters of the Arctic Central Basin. Microplastic sampling was carried out using the bow water system of icebreaker Oden (single depth: 8.5 m) and CTD rosette sampler (multiple depths: 8–4369 m). Potential microplastics were isolated and analysed using Fourier Transform Infrared Spectroscopy (FT-IR). Bow water sampling revealed that the median microplastic abundance in near surface waters of the Polar Mixed Layer (PML) was 0.7 particles m^{-3}. Regarding the vertical distribution of microplastics in the ACB, microplastic abundance (particles m^{-3}) in the different water masses was as follows: Polar Mixed Layer (0–375) > Deep and bottom waters (0–104) > Atlantic water (0–95) > Halocline i.e. Atlantic or Pacific (0–83).

1. Introduction

The Arctic Ocean, though the smallest in the world, is unique due to its distinct abiotic features and the highly specialised ecosystem it supports. Key anthropogenic drivers which may put pressure on this ecosystem include (i) climate change, (ii) harvest and fisheries, (iii) persistent, bio-accumulative and toxic contaminants, (iv) industrial development, (v) shipping, and (vi) invasive alien species (CAFF, 2017). Plastic contaminants in the world's oceans have emerged as an issue of global importance due to their ubiquitous distribution, long-range transport potential, persistence and perhaps most importantly the potential threat they pose to marine organisms (UNEP, 2011). Remote polar oceans such as the Arctic Ocean have not been immune to the entry of plastics as a combination of long-range transport processes and local anthropogenic activities have contributed to the plastic debris in these areas.

Characteristic abiotic features which set the Arctic Ocean apart from other oceanic basins include (i) a central area of perennial pack ice, (ii) seasonal extremes in solar irradiance, ice and snow cover, temperature and riverine inflow, and (iii) an upper layer of lower salinity water due to freshwater input from rivers and seasonal sea-ice melt (CAFF, 2013). This unique ecosystem is a habitat for a vast array of marine organisms, some of which are (i) endemic to the region, (ii) commercially important, (iii) apex predators, (iv) central to the functioning of the ecosystem, and (v) threatened as evidenced by their inclusion in the IUCN Red List of Threatened Species (CAFF, 2013; CAFF, 2017).

Despite its remote location away from major population centres and the low coastal population in its surrounding shelf areas, both macro and microplastics were detected in the various environmental compartments of the Arctic Ocean. Between 2002 and 2014, macroplastics were detected on the seafloor (2500 m depth) of the eastern Fram Strait at the HAUSGARTEN observatory (Bergmann and Klages, 2012; Tekman et al., 2017). Sightings of buoyant macroplastics were also made during ship and helicopter observation surveys in the Barents Sea and Fram Strait (Bergmann et al., 2016). A citizen-science study also recently reported the presence of macroplastics on six beaches of the Svalbard Archipelago (Bergmann et al., 2017a). Arctic sea ice was reported by Obbard et al. (2014) as having microplastic concentrations (38–234 particles m^3 of ice) several orders of magnitude greater than highly contaminated oceanic waters. Lusher et al. (2015) first reported on microplastic abundances in surface and sub-surface waters south and southwest of Svalbard. Amélineau et al. (2016) later reported on microplastic abundance in surface waters east of Greenland. Regarding Arctic species, microplastics have been detected in the gular pouches of Little Aulks (*Alle alle*), (Amélineau et al., 2016), as well as in the stomachs of juvenile polar cod (*Boreogadus saida*), (Kuhn et al., 2018). Microplastics were also detected in sediments (collection depths 2340–5570 m) from the Fram Strait (Bergmann et al., 2017b). Recently,

* Corresponding author at: Marine and Freshwater Research Centre, Galway Mayo Institute of Technology, Dublin Road, Galway, Ireland.
E-mail address: ladaana.kanhai@research.gmit.ie (L.D.K. Kanhai).

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results from a circumpolar expedition of the Arctic indicated that concentrations of floating plastic ranged between 0 and 320,000 items km^{-2} in the Greenland and Barents Sea and 0–27,000 items km^{-2} in the rest of the Arctic Ocean (Cózar et al., 2017).

Plastic contaminants are introduced to the Arctic Ocean due to a combination of (i) long-range transport processes, e.g. via oceanic currents, biotransport and riverine input, and (ii) local anthropogenic activities, e.g. shipping. The three oceanic currents which supply the greatest water volumes to the Arctic Ocean are the (i) West Spitsbergen Current i.e. the polar limb of the North Atlantic circulation which carries warm water from the North Atlantic Current (9.5 Sverdrup, $Sv = 10^6 m^3 s^{-1}$), (ii) a cold ocean current that enters from the Pacific Ocean via the Bering Strait (1.5 Sv) and, (iii) a branch of the North Atlantic Current, which flows along the Siberian coastline (1.0 Sv), (Zarfl and Matthies, 2010). These oceanic currents may also transport plastics to the Arctic Ocean with the estimated plastic flux to this region ranging between 62,000 to 105,000 tons per year (Zarfl and Matthies, 2010). Models based on a particle-trajectory approach for studying the fate of marine debris in the open ocean highlighted the northward transport of marine debris to polar regions and the formation of a sixth so-called garbage patch in the Barents Sea (van Sebille et al., 2012). Bio-transport is another long-range transport process via which plastics may enter polar regions. Plastic ingestion was reported in Northern Fulmars (*Fulmaris glacialis*) and Thick-billed Murres (*Uria lomvia*) in the Arctic (Mallory, 2008; Provencher et al., 2012; Trevail et al., 2015). Some studies suggested that the seabirds had ingested plastics during their wintering in the North Atlantic Ocean and had then transported the contaminants to the Arctic upon migration (Mallory, 2008; Provencher et al., 2012). Riverine discharge from Siberian (Ob, Yenisei and Lena) and Canadian (Mackenzie) rivers are other potential sources of plastics to the Arctic. Obbard et al. (2014), however, point out that the contribution of riverine discharge to plastic input in the Arctic is projected to be low due to the fact that these rivers flow through sparsely populated watersheds. Local anthropogenic activities are another source of plastics to the Arctic. Increased ship traffic due to shipping and tourism was found to be positively correlated with increased litter densities in the Fram Strait (Bergmann and Klages, 2012; Tekman et al., 2017).

The intense focus by scientists on the near-surface layer of the ocean for microplastics has been due in part to the presumption that the majority of particles would be found in this region of the water column given the inherent densities of individual synthetic polymers. Such a theorization led to traditional techniques that involved nets, manta trawls as well as the seawater intake of vessels that sampled only the upper few meters of the water column for microplastics. Yet, several studies indicated that a mismatch existed between observed and expected plastic concentrations in surface oceanic waters when estimated plastic production and projected inputs to the oceans were considered (Cózar et al., 2014; Eriksen et al., 2014). It was therefore proposed that several mechanisms potentially influenced the vertical distribution of microplastics within the water column and led to their transport out of surface waters. Some of these mechanisms included (i) incorporation into marine aggregates (Long et al., 2015), (ii) biofouling (Fazey and Ryan, 2016), (iii) incorporation into faecal matter (Cole et al., 2016) and, (iv) hydrodynamic factors such as wind (Kukulka et al., 2012). Despite the theorization that surface waters are not the ultimate repository for plastic debris in the marine environment (Cózar et al., 2014), few studies ventured beyond traditional near-surface microplastic monitoring to investigate their vertical distribution in the water column.

Microplastic pollution in the Arctic Ocean is an issue that warrants attention due to the potential threats that these contaminants may pose to the inhabitants of this unique ecosystem. A practical step towards addressing this issue and evaluating the extent of the problem involves assessing the abundance, distribution and composition of microplastics in Arctic waters. While microplastic monitoring in the marine environment has traditionally focused on surface waters, the reality is that the vast majority of marine organisms inhabit sub-surface waters. Monitoring microplastics in sub-surface waters is particularly relevant as it can also provide some insight into the whereabouts of the 'missing plastic' from surface waters. To our knowledge, the present study sought for the first time (i) to provide a spatial overview of microplastic abundance, distribution and composition in the Polar Mixed Layer (PML) of the Arctic Central Basin (ACB) and, (ii) to determine whether microplastics in the ACB were being transported out of surface waters by assessing their vertical distribution in the water column.

2. Materials and method

2.1. Study area

The Arctic Ocean is comprised of a deep central basin surrounded by extensive continental shelves (CAFF, 2013). The bathymetry of the Arctic Ocean is such that the Lomonosov Ridge separates the central basin into the Canadian (Amerasian) and Eurasian basins with the basins being further sub-divided by the (i) Gakkel Ridge, into the Amudsen and Nansen basins and, (ii) Alpha Ridge, into the Makarov

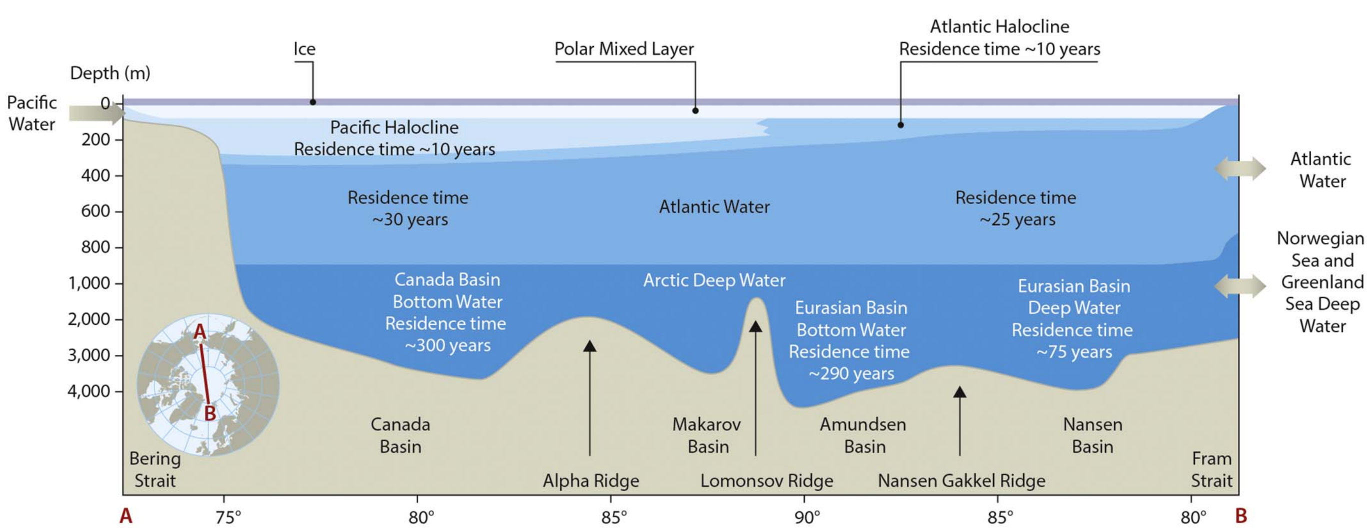

Fig. 1. General overview of the bathymetry and water masses of the Arctic Central Basin [reprinted here with permission from CAFF], (CAFF, 2013).